

Central Diffraction in Proton-Proton Collisions at $\sqrt{s} = 7$ TeV with ALICE at LHC

Felix Reidt
for the ALICE Collaboration

Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Abstract. A double-gap topology is used for filtering central-diffractive events from a proton-proton minimum-bias data sample at a centre-of-mass energy $\sqrt{s} = 7$ TeV. This topology is defined by particle activity in the ALICE central barrel and absence of particle activity outside. The fraction of events satisfying the double-gap requirement R_{DG} is found to be $7.63 \pm 0.02(stat.) \pm 0.87(syst.) \times 10^{-4}$. The background of this double-gap fraction is estimated by studying the contributions of non-diffractive, single- and double-diffractive dissociation processes as modelled by Monte Carlo event generators, and is found to be about 10%.

Keywords: Double-Gap Fraction, Central Diffraction, ALICE, LHC

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INTRODUCTION

The ALICE experiment [1] at the Large Hadron Collider (LHC) consists of the central barrel in the pseudorapidity range of $-0.9 < \eta < 0.9$ and a muon spectrometer at $-2.5 < \eta < -4.0$. Additional detectors for triggering and event classification are available in the range $-3.7 < \eta < 5.1$. Double-gap events can be identified by requiring activity in the central barrel and by the absence of activity in the more forward regions. At LHC energies, about 25 mb, i.e. one third of the inelastic hadronic cross section, are of diffractive origin as e.g. measured by ALICE in a previous study [2]. These diffractive events are mediated by a Pomeron [3] exchange. Central-diffractive events show the characteristic double-gap topology due to their double-Pomeron exchange. The central-diffractive cross section is predicted to be about $800 \mu\text{b}$ [4].

ALICE DETECTORS

This analysis focuses on the central barrel of ALICE. The innermost detector is the Inner Tracking System (ITS) which consists of six layers. The first two layers are Silicon Pixel Detectors (SPD) covering $-2.0 < \eta < 2.0$ and $-1.4 < \eta < 1.4$. The ITS is used for vertex reconstruction and, together with the Time-Projection Chamber (TPC), for tracking. In the forward region, the VZERO scintillator hodoscope for trigger purposes is located at $-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$. In addition multiplicity-density measurements can be performed by the Forward-Multiplicity Detector (FMD) situated at $-3.4 < \eta < -1.7$ and $1.7 < \eta < 5.0$. It is a silicon strip detector built for multiplicity density measurements. The low material budget and low magnetic field of 0.5 T lead

to a low single particle p_T -threshold of 17 MeV/ c for 50% detection efficiency. Further details on the ALICE detector system can be found in [1].

DOUBLE-GAP TOPOLOGY

Central diffraction results from the two incoming protons interacting via double-Pomeron fusion. The centrally produced system is accompanied by large rapidity gaps. In central diffractive processes, the protons can either stay intact or break up. The double-gap topology can be exploited as filter for central diffraction. However, at topology level, Pomeron, Reggeon or photon exchanges cannot be distinguished. The contribution from Reggeon exchanges is assumed to be comparable to lower energies, while the Pomeron contribution is expected to increase with energy. The ALICE pseudorapidity coverage and the corresponding gap definitions are shown in Fig. 1. The gaps are defined by the absence of activity induced by the passage of particles in the trigger signals of VZERO, FMD and SPD in the pseudorapidity ranges of $-3.7 < \eta < -0.9$ and $0.9 < \eta < 5.1$. The central activity is determined using SPD in the range of $-0.9 < \eta < 0.9$. This double-gap configuration is a trade-off of large gaps suppressing background and a reasonable coverage for the centrally produced signal.

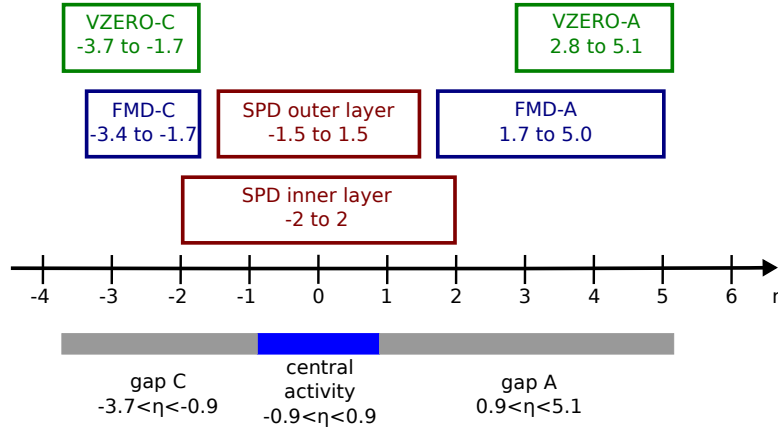


FIGURE 1. ALICE η coverage by individual detectors used in this study and double-gap topology.

ANALYSIS

The double-gap analysis is based on minimum-bias data at $\sqrt{s} = 7$ TeV taken during the 2010 run. This data set was acquired at low luminosity and low event pileup. The minimum-bias trigger is the logical-OR of the two VZERO and the SPD trigger signal, called MB_{or} . A total of 300 million MB_{or} triggers are used for this analysis. Luminosity determination within this data sample is possible by using the minimum-bias cross section σ_{MBand} available from van-der-Meer scans and the MB_{and} trigger count. The MB_{and} trigger is derived from the coincidence of the two VZERO subdetectors. Furthermore, a monitoring of the gap-fraction for all involved detectors is done on a

run-by-run basis. Runs deviating by more than 3σ from the data-taking period mean are rejected. In addition to the run selection, an event selection is applied. Furthermore, a vertex within ± 4 cm of the interaction point in direction of the beam axis is required to ensure a continuous gap coverage. Moreover, pileup is rejected by identifying multiple vertices reconstructed from the SPD information. The number of double-gap events N_{DG} and the number of MB_{AND} events N_{MBand} are analysed on a run-by-run basis.

First data-driven systematic-error estimates are available. The event selection can influence the ratio of N_{DG} to N_{AND} , due to the vertex requirement. For example, double-diffractive dissociative events do not necessarily contain a vertex. This effect is estimated to be about 6%. Furthermore, the central activity can be missed, leading to a bias to lower cross section of approximately 5%. On the contrary, missing a particle in the gap shifts the cross section about 5% towards higher values. The uncorrelated error contribution is estimated to be 1.4% from the spread of the data-taking period means.

DOUBLE-GAP FRACTION

The double-gap fraction R_{DG} is a measure for the potential amount of central-diffractive events within the minimum-bias data. In the ALICE proton-proton data it is found to be

$$R_{DG}(\underbrace{2.8}_{\Delta\eta_1}, \underbrace{\pm 0.9}_{\eta_{act}}, \underbrace{4.2}_{\Delta\eta_2}) = \frac{N_{DG}}{N_{MBand}} = (7.63 \pm 0.02(stat.) \pm 0.95(syst.)) \cdot 10^{-4}. \quad (1)$$

In Fig. 2, the fraction R_{DG} is shown as a function of the run number. It shows a very uniform behaviour and no apparent dependence on the run conditions.

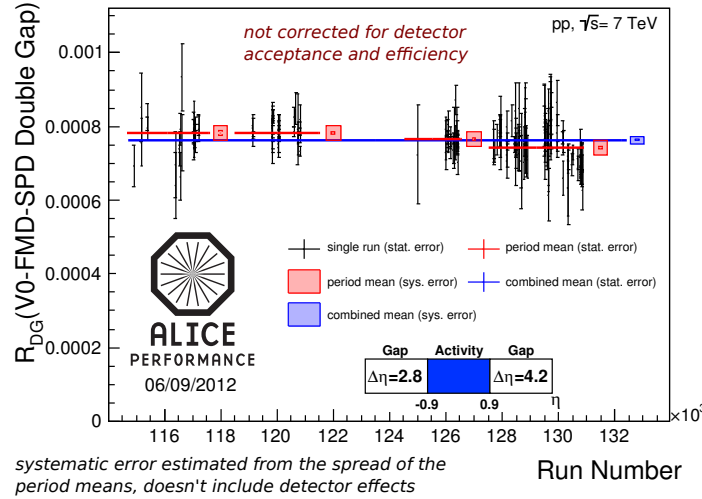


FIGURE 2. Double-gap fraction in proton-proton collisions at $\sqrt{s} = 7$ TeV.

COMPARISON TO MONTE CARLO GENERATORS

The data simulated using PHOJET and PYTHIA6 were used in order to estimate the amount of non-diffractive, single and double diffractive-dissociative interactions having

a double-gap topology. Both PHOJET and PYTHIA6 are used with a tune for single and double diffractive dissociation but without central diffraction [2] in order to generate the data set for comparisons. However, further tuning is needed since generator multiplicity distributions are too low by up to 30% and 40% in the central and forward region, respectively. A first estimate of the bias caused by this deviation assumes the gaps to be uncorrelated and the multiplicity to be distributed according to a negative binomial distribution. This estimate leads to a reduction of the double-gap fraction seen in MC data as shown in Table 1. Both generators are unable to describe the double-gap fraction

TABLE 1. Double-gap fraction in Monte Carlo datasets, before and after first tuning

	$R_{DG}(\text{PYTHIA6})$	$R_{DG}(\text{PHOJET})$
not tuned for multiplicity	$3.4 \cdot 10^{-4}$	$0.5 \cdot 10^{-4}$
first tuning	$1.0 \cdot 10^{-4}$	$0.2 \cdot 10^{-4}$

$7.63 \cdot 10^{-4}$ observed in ALICE data. These findings can be interpreted as hints for central diffraction, since the simulated background amounts only to about 10%. However, the ALICE acceptance and efficiency for central-diffractive events need to be studied using Monte Carlo data.

SUMMARY AND OUTLOOK

ALICE is well suited to measure central diffraction due to the low p_T -threshold and the low luminosity data set. The double-gap fraction derived from data of $7.63 \pm 0.02(stat.) \pm 0.87(syst.) \cdot 10^{-4}$ is in excess by about a factor 10 over the expected background simulated by PYTHIA6 and PHOJET. The evaluation of systematic uncertainties will be refined in the future by tuning the MC simulations of the backgrounds and the gap signal will be turned into a cross section measurement making the result more universal. Further studies will determine the properties of this signal by studying the gap-size dependence of the double-gap fraction and specific states.

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